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Ballston Tower One
800 North Quincy Street
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Attn: Dr. Jeff Simmen, Code 321

Subj: Semi-annual Performance Report on "Multiple Scatter Theory of Ocean Sediments," under Grant No. N00014-94-1-0438, for the period 1 August 1994 through 31 January 1995

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Encl: (1) Semi-annual performance report
(2) Material Inspection and Receiving Report (DD Form 250) ASG0276

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To develop a new model of acoustic bottom backscatter from sandy sediments, based on a multiple scattering theory approach, and hence, properly explain observed phenomena, including Lambert's rule and frequency dependence of backscattering strength, particularly at shallow grazing angels, for which current theories are at a loss.

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Semi-Annual Performance Report
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1 August 1994 - 31 January 1995

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Long-term goals:

To develop a new model of acoustic bottom backscatter from sandy sediments, based on a multiple scattering theory approach, and hence, properly explain observed phenomena, including Lambert's rule and frequency dependence of backscattering strength, particularly at shallow grazing angles, for which current theories are at a loss.

Scientific Objectives:

The idea underlying our current approach to this problem is that real sediments are granular. The hypothesis we are trying to prove is that physical mechanisms for both attenuation and scattering may be found in the interaction of acoustic waves with the granular structure.

Background:

The process of scattering of sound by the interior of the ocean sediment has two components: the conduction of acoustic energy into the sediment and the scattering mechanism. Results of recent sandy bottom penetration experiments by Chotiros[1,2] have shown that Biot's theory[3] is the most plausible model of the conduction process, particularly at shallow grazing angles. The scattering mechanism itself is not well understood. Current theories, such as the composite roughness scattering model by Jackson[4] and the volume scattering models by Ivakin[5], require a degree of sediment surface

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roughness to conduct energy into the sediment interior at subcritical grazing angles, and are unable to explain experimentally observed backscattering from a smooth sand surface.

Progress in the period 1 August 1994 to 31 January 1995:

Our initial attempt was simply to consider the case of a uniformly layered Biot medium, where each layer has a thickness on the order of one grain diameter. The layers within the sediment alternate between two values of porosity centered on a mean value of 0.36. The reflection coefficient was found to oscillate with increasing sediment thickness without any perceptible loss. This steady oscillation is what one would expect for a lossless sediment, due to interference between the reflection from the top and bottom surfaces of the sediment. Thus, this simulated sediment was unable to duplicate the attenuation seen experimentally in porous media.

The second stage of the study was to randomize the thickness of the layers/grains. This produced a sharp dampening in the oscillations of the reflection coefficient. Since this is one of the effects of adding nonzero bulk and shear logarithmic decrements to the layers of the inhomogeneous sediment, the grain size distribution may partially account for these two parameters. However, the asymptotic value of the reflection coefficient as the sediment thickness increases was found to fluctuate wildly from one simulation to the next. No pattern could be found that would explain these fluctuations.

Subsequent simulations revealed that the fluctuations could be dramatically reduced by correlating the thickness and porosity of the layers in the inhomogeneous sediment. Thus, the thickness and porosity were correlated in such a way that each layer represents a monolayer of granular material, of uniform grainsize, and an adjacent fluid gap. For a monolayer of particular grainsize, greater layer thickness implies greater porosity.

The simulations currently in progress employ this approach of correlating porosity with layer thickness. For a given sediment, the grainsize distribution is a single-peaked function with a mean and standard deviation matching one of the grainsize distributions used in the experimental work of Nolle[6] and Mifsud[7]. The dimensionless standard deviation of the layer thickness distribution is

chosen to be the same as for the grainsize distribution. Thus, the free parameters of the simulations are the mean and standard deviation of the grainsize distribution. Lateral variations in the layers are simulated by performing a coherent ensemble average of the results for several distinct layer profiles, where each profile in an ensemble conforms statistically to the same grainsize distribution.

Transition/integration expected:

The result will lead to a unified theory of propagation and scattering in porous media, applicable to ocean sediments over a broad range of frequencies, which will replace much of the disjointed collection of submodels currently in use, and which will properly explain the observed frequency, grain size and grazing angle dependencies. After follow-on laboratory experimental verification, the results of this project will transition into sonar performance prediction models, such as the sonar performance models under development in the Mine Counter Measure Tactical Environmental Data System (MTEDS) project.

Relationship to other projects:

There is a parallel effort funded by Naval Research Laboratory (NRL) that uses a different approach. The two approaches are complementary.

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